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Heterotic Response, Inbreeding Depression and Combining Ability (GCA & SCA) Effects Analysis for Seed Yield and Its Component Traits in Yellow Sarson (*Brassica rapa* var. Yellow Sarson)

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ABSTRACT

The analysis of variance indicated significant differences among the treatments for all the characters. Parents vs. F_1s, parents vs. F_2s and F_1s vs. F_2s also revealed highly significant differences for all the characters except harvest index and oil content. The estimate of $\hat{\sigma}^2 g$ were lower than $\hat{\sigma}^2 s$ for all the characters. The analysis of variance for combining ability were found significant differences for all the characters except biological yield per plant in F_1 and F_2 generations. The parents namely, YSC-41, B-09, YSC-76, YSKM-11-1 and YSKM-10-02 were found common good general combiners in both F_1 and F_2 generations based on gca effect and per se performance for seed yield per plant. The cross combinations namely, YSC-63 x YSH-401, YSC-41 x NRCYS-05-02, YSC-41 x YST-151, B-09 x YSH-401 and B-09 x YST-151 were found common good specific combiners in both F_1 and F_2 generations on the basis of sca effects and per se performance for seed yield per plant. The cross combinations namely, B-09 x YST-151, YSKM-10-02 x YST-151, YSC-15 x YST-151, YSC-30 x YST-151 and YSC-84 x YST-151 were shown desirable and significant heterotic response over better and economic parent and high inbreeding depression for seed yield per plant.

Key words: *Heterotic response, Brassicas, Vitamins, Minerals, Proteins*

INTRODUCTION

The *Brassicaceae*, contains about 3500 species and 350 genera, is one of the ten most economically important plant family, it is distinguished on the basis of the presence of counduplicate cotyledons (i.e. the cotyledons are longitudinally folded around the radical) and two segment fruits (siliquae), which contain seeds in one or both segments, and only simple hairs, if present. Crop *Brassicas* encompass many diverse types of plants, which are grown as vegetables, fodder or sources of oils and condiments. Mustard oil contains vitamins, minerals, proteins and carbohydrate. It has been reported that 100g of mustard oil produce a sizeable amount of erucic acid (52.2%) and linolenic acid (12.4%).

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The protein content in mustard ranges between 24-30% on the whole seed basis and between 34-40% on meal basis. When compared to other edible oils, the rapeseed/mustard oil has the lowest amount of harmful saturated fatty acids. It also contains adequate amounts of the two essential fatty acids, linoleic and linolenic, which are not present in many of the other edible oils. The per capita consumption of oil in India is still very low in comparison to many other countries of the world. The consumption of vegetable oil in our country is roughly 12.4 kg/head/ year.

MATERIALS AND METHODS

The experimental materials were comprised 25 lines namely, YSC-63, YSC-41, B-09, YSK-71, YSKM-11-02, YSC-76, YSKM-10-1, YSKM-11-1, YSC-75, YSKM-10-02, YSK-9-01, YSC-80, K-88, YSC-15, Type-42, YSC-18, YSK-03, YSC-21, YSC-92, YSC-45, YSC-30, YSC-95, YSC-40, YSC-46 and YSC-46 used as female and 4 testers namely, NRCYS-05-02, YSH-401, YST-151 and Pitambari (check) used as male of yellow sarson. The materials comprising of 29 parents + 100 F_1s + 100 F_2s were sown in Randomized Block Design with three replications during *Rabi* 2014-2015 at Oilseed Research Farm, Kalyanpur of C.S. Azad University of Agriculture & Technology, Kanpur-208002. All the Twenty five females were crossed with each of four males in line x tester mating deigns to produce sufficient amount of F_0 seeds of 100 crosses during the *Rabi* season 2011-12 to raise the F_1s. The F_1s were selfed in order to obtain F_2s seeds during the *Rabi* season 2012-13. The parents were also maintained through selfing in a Randomized Block Design (RBD) with three replications at the Oilseed Research Farm, Kalyanpur of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Each treatment was planted in one row, of 3 m length and 45 cm apart, Plant to plant distance was maintained at 15 cm by thinning. All the recommended agronomic practices were adopted for raising a good crop. The observations were recorded on eight characters namely; number of siliquae per plant, number of seeds per siliqua, biological yield per plant (g), harvest index (%), 1000-seed weight (g), oil content (%), protein content (%) and seed yield per plant. The analysis of variance for combining ability was carried out according to the method outlined by Kempthorne[1]. The oil content (% seed weight) and protein content (% de-oiled meal weight) was estimated by using Nuclear Magnetic Resonance (NMR) method.

RESULTS AND DISCUSSION

The results of analysis of variance are presented in Table-1. The analysis of variance indicated significant differences among the treatments for all the characters. Highly significant differences were observed among replications, treatments, parents, lines, testers, line x testers, F_1s, F_2s, parents vs F_1s, parents vs F_2s, parents vs F_1s +F_2s, F_1s vs F_2s for all the eight characters. Similar findings were also observed by Sharma *et al.*[14], Raj *et al.*[11].

The analysis of variance for combining ability are presented in Table-2. The estimate of $\hat{\sigma}^2 g$ were lower than $\hat{\sigma}^2 s$ for all the characters in both the generations. The ratio of $\hat{\sigma}^2 g / \hat{\sigma}^2 s$ was less than 1.0 in all the attributes. The ratio of $\hat{\sigma}^2 g / \hat{\sigma}^2 s$ was greater than unity in F_1 generations. The average degree of dominance $[\hat{\sigma}^2 s / \hat{\sigma}^2 g]^{0.5}$ was more than unity for all the characters in both F_1 and F_2 generations showing over dominance in these attributes. Similar results were also reported by Sharma *et al.*[15], Singh *et al.*[23], Singh *et al.*[18], Gupta *et al.*[6] and Singh *et al.*[25].

The general combining ability (gca) effects are presented in table-3. The parents namely; YSC-41, YSC-40, YSC-46, NRCYS-05-02, YSH-401, YST-151 and Pitambari were found common good general combiners in both F_1 and F_2 generations on the basis of *per se* performance for number of siliquae per plant. It indicate that these lines will be produce more number of siliquae per plant. Similar findings was also reported by Sweta *et al.*[12].

The parents namely; YSC-71, YSKM-10-02, YSC-45 and YSC-40 were found common good general combiners in F_1 and F_2 generations on the basis of *per se* performance for number of seeds per siliqua. Similar results was also observed by Tripathi *et al.*[27].

The parents namely; B-09, YSC-75, YSC-15, T-42, YSC-18, YSC-21, YSC-45 and YSC-40 were found common good general combiners in F_1 and F_2 generations on the basis of *per se* performance for biological yield per plant. The parents namely; YSC-41, YSKM-11-02, YSKM-10-01, YSC-80, YSC-18, YSC-92, YSC-45, YSC-40, YSC-46, NRCYS-05-02 and YST-151 were found common good general combiners in both F_1 and F_2 generations on the basis of *per se* performance for harvest index. The parents namely; T-42, YSC-30, YSC-40, YSH-401, YST-151 and Pitambari were found common good general combiners in both F_1 and F_2 generations on the basis of *per se* performance for 1000-seed weight. The parents namely, B-09, YSC-76, nrcys-05-02 and Pitambari were found common good general combiners in both F_1 and F_2 generations on the basis of *per se* performance for oil content. The parents namely; YSC-41, YSC-71, YSKM-11-1, YSC-45, TSC-95, YSH-401 and YST-151 were found common good general combiners in both F_1 and F_2 generations on the basis of *per se* performance for protein content and the parents namely; YSC-71, YSK-9-01, YSC-80, T-42, YSK-03, YSC-45, YSC-40, YSC-84, NRCYS-05-02 and Pitambari were found common good general combiners in both F_1 and F_2 generations on the basis of *per se* performance for seed yield per plant. Similar findings were also observed by Singh *et al.*[17] and Singh *et al*[24].

The specific combining ability effects (sca) are presented in table-4. Out of 100 crosses top five best cross combinations namely; YSC-95 x Pitambari, YSC-40 x NRCYS-05-02, YSC-46 x NRCYS-05-02, YSC-84 x YSH-401 and YSC-84 x YST-151 were found common good specific combiners in both F_1 and F_2 generations on the basis of *per se* performance for number of siliquae per plant. The cross combinations namely; T-42 x NRCYS-05-02, YSK-03 x YST-151, YSC-45 x NRCYS-05-02, YSC-95 x YST-151 and YSC-84 x NRCYS-05-02 were found common good specific combiners in both F_1 and F_2 generations on the basis of *per se* performance for number of seeds per siliqua. Similar findings were also reported by Singh *et al.*[22].

The cross combinations namely; B-09 x NRCYS-05-02, YSKM-11-1 x NRCYS-05-02, K-88 x NRCYS-05-02, YSC-21 x NRCYS-05-02 and YSC-40 x NRCYS-05-02 were found common good specific combiners on the basis of *per se* performance and sca effects in F_1 generations but in F_2 generations. These crosses were found desirable only *per se* performance not in sca effects for biological yield per plant. The cross combinations namely; YSC-41 x NRCYS-05-02, YSC-71 x YST-151, YSC-95 x NRCYS-05-02, B-09 x YST-151 and YSC-46 x YST-151 were found good specific combiners in both F_1 and F_2 generations on the basis of sca effects and *per se* performance for harvest index. The cross combinations namely; YSC-41 x NRCYS-05-02, YSC-41 x YST-151, YSC-71 x YST-151, B-09 x YST-151 and YSKM-11-02 x NRCYS-05-02 were found good specific combiners on the basis of sca effects and *per se* performance in both F_1 and F_2 generations for 1000-seed weight. The cross combinations namely; T-42 x NRCYS-05-02, YSC-21 x NRCYS-05-02, YSC-45 x NRCYS-05-02, YSC-30 x NRCYS-05-02 and YSC-46 x NRCYS-05-02 were found common good specific combiners in both F_1 and F_2 generations on the basis of *per se* performance for oil content. Similar findings was also observed by Singh *et al.*[17],

The cross combinations namely; YSC-95 x YST-151, YSC-40 x YSH-401, YSC-46 x YSH-401, YSC-84 x NRCYS-05-02 and YSC-84 x Pitambari were found common good specific combiners in both F_1 and F_2 generations on the basis of both sca effects and *per se* performance for protein content and the cross combination namely; YSC-63 x YSH-401, YSC-41 x NRCYS-05-02, YSC-41 x YST-151, B-09 x YSH-401 and B-09 x YST-151 were common good specific combiners in both F_1 and F_2 generations on the basis of sca effects and *per se* performance for seed yield per plant. Similar results was also observed by Singh *et al*[16].

Heterosis was calculated in per cent over better as well as economic parents for all the seven characters. Estimate of inbreeding depression in F_2s over their respective F_1s were calculated in terms of percentage. The results of heterosis and inbreeding depression are shown in table-5. The top five best cross combinations namely; YSC-92 x NRCYS-05-02, YSC-45 x NRCYS-05-02, YSC-95 x NRCYS-05-02, YSC-40 x NRCYS-05-02 and YSC-84 x NRCYS-05-02 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for more number of siliquae per plant. Similar findings were also reported by Singh *et al.*[21] and Singh *et al.*[22].

The cross combinations namely; YSC-45 x NRCYS-05-02, YSC-95 x YSH-401, YSC-95 x YST-151, YSC-46 x Pitambari and YSC-84 x NRCYS-05-02 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for more number of seeds per siliqua. The cross combinations namely; YSC-45 x YSH-401, YSC-30 x Pitambari, YSC-95 x Pitambari, YSC-46 x YSH-401 and YSC-84 x YSH-401 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for biological yield per plant. The cross combinations namely; YSC-45 x YSH-401, YSC-30 x NRCYS-05-02, YSC-95 x Pitambari, YSC-40 x YST-151 and YSC-84 x YSH-401 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for harvest index. The cross combinations namely; T-42 x NRCYS-05-02, T-42 x YST-151, YSK-03 x YST-151, YSC-45 x NRCYS-05-02 and YSC-95 x YST-151 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for 1000-seed weight. Similar results were also reported by Chauhan *et al.*[3] and Prajapati *et al.*[8].

The cross combinations namely; YSC-92 x YST-151, YSC-45 x YST-151, YSC-30 x YST-151, YSC-46 x YST-151 and YSC-84 x YST-151 were shown positive and significant heterosis over both better and economic parent for oil content. The cross combinations namely; YSC-95 x YST-151, YSC-40 x YSH-401, YSC-46 x YSH-401, YSC-84 x NRCYS-05-02 and YSC-84 x Pitambari were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for protein content and the cross combinations namely; B-09 x YST-151, YSKM-05-02 x YST-151, YSC-15 x YST-151, YSC-30 x YST-151 and YCS-84 x YST-151 were shown positive and significant heterosis over both better and economic parent and high inbreeding depression for seed yield per plant. These findings were also reported by Lal *et al.*[7] and Dutta *et al.*[4].

Table 1: ANOVA for eight characters in line x tester analysis of yellow sarson (*Brassica rapa var. yellow sarson*): mean sum of squares (Parents + F_1s + F_2s)

Sources of variance	d.f.	Number of siliquae per plant	Number of seeds per siliqua	Biological yield per plant (g)	Harvest index (%)	1000-seed weight (g)	Oil content (%)	Protein content (%)	Seed yield per plant (g)
Replications	2	124.05**	7.24	14.29**	3.60	0.70**	9.94**	0.46**	0.33**
Treatments	228	49.25**	15.81**	11.31**	5.59**	1.59**	3.15**	5.65**	2.02**
Parents	28	43.96**	5.23**	5.15**	2.91**	0.77**	2.70**	4.10**	1.77**
Lines	24	27.97**	5.13**	4.97*	2.44**	0.64**	2.96**	4.11**	1.70**
Testers	3	30.97**	7.66**	8.00*	5.10**	0.11**	0.28**	2.55**	2.20**
Lines x Testers	1	466.69**	0.20	0.73	7.42*	5.85**	3.55**	8.45*8	2.18**
F_1s	99	15.54**	7.17**	15.69**	5.10**	0.52**	2.60**	3.17**	1.37**
F_2s	99	30.02**	5.62**	1.63	5.85**	1.36**	2.66**	3.27**	1.55**
Parents Vs F_1s	1	2274.14**	2175.31**	211.32**	88.68**	50.67**	106.14**	498.75**	114.75**
Parents Vs F_2s	1	1.33**	1122.28**	8.90*	102.98**	0.93**	109.66**	445.05**	99.04**
Parents Vs F_1s+F_2s	1	671.84**	1808.97**	37.60**	107.81**	10.66**	121.56**	531.23**	120.27**
F_1s Vs F_2s	1	4816.67**	384.00**	682.67**	1.19	145.34**	0.06	3.40**	1.29**
Error	456	1.39	2.69	2.23	1.29	0.01	1.25	0.04	0.02

***, ** significant at 5 and 1 per cent level, respectively**

Table 2: ANOVA (MSS) for combining ability effects for eight characters in line x tester cross analysis of yellow sarson (*Brassica rapa* var. yellow sarson)

Source of variation	d.f.	G	Number of siliquae per plant	Number of seeds per	Biological yield per plant (g)	Harvest index (%)	1000-seed weight	Oil content (%)	Protein content (%)	Seed yield per plant (g)
Replicates	2	F_1	12.49**	6.33	0.09	0.67	0.04	1.83	0.12	0.01
		F_2	5.49*	6.84	4.33	0.41	0.05*	1.69	0.04	0.01
Lines	24	F_1	14.49	6.13	23.36	4.86	0.05	1.17	2.59	0.41
		F_2	8.83	3.14	0.50	1.33	1.47	1.62	2.11	0.70
Testers	3	F_1	53.77*	9.00	21.77	4.86	0.05	1.17	2.59	0.41
		F_2	160.44**	5.44	4.00	39.85**	1.36	11.76**	9.27	0.24
Line x Tester	72	F_1	14.29**	7.43**	12.87**	4.40**	0.11**	1.87*	3.17**	1.73**
		F_2	31.64**	6.45**	1.90	5.93**	1.32**	2.62**	3.40**	1.88**
Crosses	99	F_1	15.54**	7.16**	15.69**	5.10**	0.51**	2.60**	3.17**	1.36**
		F_2	30.02**	5.62**	1.60	5.84**	1.36**	2.65**	3.27**	1.54**
Error	198	F_1	1.75	2.86	2.65	1.31	0.01	1.30	0.05	0.01
		F_2	1.79	2.42	1.64	1.30	0.01	1.31	0.02	0.02
Total	299	F_1	6.39	4.31	6.95	2.56	0.18	1.73	1.08	0.45
		F_2	11.16	3.51	1.65	2.80	0.46	1.76	1.10	0.53

***, ** significant at 5 and 1 per cent level, respectively**

Table 3: Estimate of general combining ability (gca) effects for eight characters in F_1 and F_2 generations of yellow sarson (*Brassica rapa* var. yellow sarson)

Parents	Number of siliquae / plant		Number of seeds / siliqua		Biological yield per plant (g)		Harvest index (%)	
Lines	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**
YSC-63	-0.02	0.57	-0.63	0.13	-1.83**	0.38	-0.52	0.10
YSC-41	0.98*	-0.10	1.03*	0.13	2.00**	-0.20	1.12**	-0.01
B-09	-1.77**	0.57	-0.88	-0.95*	-1.17*	-0.03	-0.64	0.01
YSC-71	1.23**	-1.60**	0.03	0.55	0.25	-0.03	0.05	0.46
YSKM-11-02	-0.43	0.57	0.45	0.13	0.75	-0.12	-0.02	-0.56
YSC-76	-0.02	0.57	-0.63	0.13	-1.83**	0.38	-0.52	0.10
YSKM-10-1	0.98*	-0.10	1.03*	0.13	2.00**	-0.20	1.12**	-0.01
YSKM-11-1	-1.77**	0.57	-0.88	-0.95*	-1.17*	-0.03	-0.64	0.01
YSC-75	1.23**	-1.60**	0.03	0.55	0.25	-0.03	0.05	0.46
YSKM-10-02	-0.43	0.57	0.45	0.13	0.75	-0.12	-0.02	-0.56
YSK-9-01	-0.02	0.57	-0.63	0.13	-1.83**	0.38	-0.52	0.10
YSC-80	0.98*	-0.10	1.03*	0.13	2.00**	-0.20	1.12**	-0.01
K-88	-1.77**	0.57	-0.88	-0.95*	-1.17*	-0.03	-0.64	0.01
YSC-15	1.23**	-1.60**	0.03	0.55	0.25	-0.03	0.05	0.46
T-42	-0.43	0.57	0.45	0.13	0.75	-0.12	-0.02	-0.56
YSC-18	-0.02	0.57	-0.63	0.13	-1.83**	0.38	-0.52	0.10
YSK-03	0.98*	-0.10	1.03*	0.13	2.00**	-0.20	1.12**	-0.01
YSC-21	-1.77**	0.57	-0.88	-0.95*	-1.17*	-0.03	-0.64	0.01
YSC-92	1.23**	-1.60**	0.03	0.55	0.25	-0.03	0.05	0.46
YSC-45	-0.43	0.57	0.45	0.13	0.75	-0.12	-0.02	-0.56
YSC-30	-0.02	0.57	-0.63	0.13	-1.83**	0.38	-0.52	0.10
YSC-95	0.98*	-0.10	1.03*	0.13	2.00**	-0.20	1.12**	-0.01
YSC-40	-1.77**	0.57	-0.88	-0.95*	-1.17*	-0.03	-0.64	0.01
YSC-46	1.23**	-1.60**	0.03	0.55	0.25	-0.03	0.05	0.46
YSC-84	-0.43	0.57	0.45	0.13	0.75	-0.12	-0.02	-0.56
Testers								
NRCYS-05-02	0.73**	1.27**	-0.30	0.23	0.47*	0.20	0.49**	-0.63**
YSH-401	-0.73**	-1.27**	0.30	-0.23	-0.47*	-0.20	-0.49**	0.63**
YST-151	0.73**	1.27**	-0.30	0.23	0.47*	0.20	0.49**	-0.63**
Pitambari (Check)	-0.73	-1.27**	0.30	-0.23	-0.47*	-0.20	-0.49**	0.63*8
SE(gi) ±	0.65	0.65	0.96	0.86	0.92	0.66	0.43	0.43

Table-3: Continue…….

Parents	1000-Seed weight (g)		Oil content (%)		Protein content (%)		Seed yield per plant (g)	
Lines	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**	**F_1**	**F_2**
YSC-63	0.10*	-0.30**	0.52	-0.06	-0.59**	-0.58**	-0.29**	-0.47**
YSC-41	0.01	-0.05	-0.17	0.15	0.32**	0.15**	0.08**	0.05
B-09	-0.01	0.47**	-0.20	-0.34	-0.40**	-0.27**	0.10**	0.14**
YSC-71	0.01	-0.42**	0.17	-0.34	0.01	0.14**	0.03	0.05
YSKM-11-02	-0.11**	0.30**	-0.32	-0.24*	0.66**	0.64**	-0.18**	-0.17**
YSC-76	0.10*	-0.30**	0.52	0.50	-0.59**	-0.32**	0.30**	0.40**
YSKM-10-1	0.01	-0.05	-0.17	0.16	0.32**	0.37**	-0.21**	-0.15**
YSKM-11-1	-0.01	0.47**	-0.20	-0.10	-0.40**	-0.37**	0.09**	-0.25**
YSC-75	0.01	-0.42**	0.17	0.06	0.01	0.16**	-0.11**	0.22**
YSKM-10-02	-0.11**	0.30**	-0.32	-0.68	0.66**	0.65**	0.27**	0.02
YSK-9-01	0.10*	-0.30**	0.52	-0.22	-0.59**	-0.45**	-0.03	-0.29**
YSC-80	0.01	-0.05	-0.17	0.50	0.32**	0.36**	-0.29**	0.11*
K-88	-0.01	0.47**	-0.20	0.15	-0.40**	-0.65**	0.08**	0.14**
YSC-15	0.01	-0.42**	0.17	-0.32	0.01	0.09**	0.10**	0.05
T-42	-0.11**	0.30**	-0.32	0.50	0.66**	0.51**	0.03	0.11*
YSC-18	0.10*	-0.30**	0.52	-0.19	-0.59**	-0.60**	-0.18**	-0.33**
YSK-03	0.01	-0.05	-0.17	-0.22	0.32**	0.27**	0.30**	0.07
YSC-21	-0.01	0.47**	-0.20	0.50	-0.40**	-0.52**	-0.21**	-0.07
YSC-92	0.01	-0.42**	0.17	-0.19	0.01	-0.04**	0.09**	0.28**
YSC-45	-0.11**	0.30**	-0.32	-0.74*	0.66**	0.46**	-0.11**	0.02
YSC-30	0.10*	-0.30**	0.52	0.50	-0.59**	-0.27**	0.27**	-0.29**
YSC-95	0.01	-0.05	-0.17	0.24	0.32**	0.27**	-0.03	0.54**
YSC-40	-0.01	0.47**	-0.20	0.08	-0.40**	-0.48**	-0.29**	-0.15**
YSC-46	0.01	-0.42**	0.17	0.50	0.01	0.02**	0.08**	-0.25**
YSC-84	-0.11**	0.30**	-0.32	-0.19	0.66**	0.48**	0.10**	0.22**
Testers								
NRCYS-05-02	0.37**	0.12**	0.56**	0.36**	-0.28**	-0.31**	0.01	-0.06**
YSH-401	-0.37**	-0.12**	-0.56**	-0.36**	0.28**	0.32**	0.04**	0.03
YST-151	0.37**	0.12**	0.56**	0.33*	-0.28**	-0.30**	0.02	0.06**
Pitambari (Check)	-0.37**	-0.12**	-0.56**	-0.33*	0.28**	0.29**	-0.06*8	-0.03
SE(gi) ±	0.00	0.00	0.42	0.42	0.01	0.01	0.00	0.00

***, ** significant at 5 and 1 per cent level, respectively**

Table 4: Estimate of specific combining ability (sca) effects and *per se* performance of F_1 and F_2 generations for eight characters in yellow sarson (*Brassica rapa* var. yellow sarson)

Characters	Cross Combinations	Generations			
		F_1		F_2	
		SCA	Mean	SCA	Mean
Number of siliquae per plant	YSC-95 x Pitambari	082**	144.66	4.43**	141.00
	YSC-40 x NRCYS-05-02	2.77**	145.33	1.23**	141.00
	YSC-46 x NRCYS-05-02	0.10**	145.66	3.40**	141.00
	YSC-84 x YSH-401	2.23**	144.66	3.77**	141.00
	YSC-84 x YST-151	1.43**	145.33	1.23**	141.00
Number of seeds per siliqua	T-42 x NRCYS-05-02	1.88**	33.00	1.27**	31.00
	YSK-03 x YST-151	1.30**	33.00	1.27**	31.00
	YSC-45 x NRCYS-05-02	1.88**	33.00	1.27**	31.00
	YSC-95 x YST-151	1.30**	33.00	1.27**	31.00
	YSC-84 x NRCYS-05-02	1.88**	33.00	1.27**	31.00
Biological yield per plant (g)	B-09 x NRCYS-05-02	3.03**	34.33	0.03**	30.00
	YSKM-11-1 x NRCYS-05-02	3.03**	34.33	0.03**	30.00
	K-88 x NRCYS-05-02	3.03**	34.33	0.03**	30.00
	YSC-21 x NRCYS-05-02	3.03**	34.33	0.03**	30.00

	YSC-40 x NRCYS-05-02	3.03**	34.33	0.03**	30.00
Harvest index (%)	YSC-41 x NRCYS-05-02	0.65**	34.86	1.84**	35.18
	YSC-71 x YST-151	0.42**	34.86	1.36**	35.18
	YSC-95 x NRCYS-05-02	0.65**	34.86	1.84**	35.18
	YSC-46 x YST-151	0.42**	34.86	1.36**	35.18
	B-09 x YST-151	1.71**	35.45	0.87**	32.50
1000-Seed weight (g)	YSC-41 x NRCYS-05-02	0.05**	4.46	0.34**	3.55
	YSC-41 x YST-151	0.70**	34.61	1.43**	31.91
	YSC-71 x YST-151	0.05**	4.46	0.71**	3.55
	YSKM-11-02 x NRCYS-05-02	0.44**	34.81	0.89**	31.91
	B-09 x YST-151	0.34**	4.83	0.88**	2.85
Oil content (%)	T-42 x NRCYS-05-02	0.49**	42.55	0.12**	42.57
	YSC-21 x NRCYS-05-02	0.47**	42.64	0.12**	42.57
	YSC-45 x NRCYS-05-02	0.49**	42.55	1.19**	42.64
	YSC-30 x NRCYS-05-02	0.32**	42.57	0.12**	42.57
	YSC-46 x NRCYS-05-02	0.02**	42.57	0.12**	42.57
Protein content (%)	YSC-95 x YST-151	1.27**	27.83	1.39**	27.57
	YSC-40 x YSH-401	1.60**	27.67	1.43**	27.64
	YSC-46 x YSH-401	0.82**	27.46	1.10**	27.52
	YSC-84 x NRCYS-05-02	0.94**	27.67	1.16**	27.52
	YSC-84 x Pitambari	0.54**	27.83	0.55**	11.05
Seed yield per plant (g)	YSC-63 x YSH-401	0.21**	11.37	0.19**	12.59
	YSC-41 x NRCYS-05-02	0.69**	12.65	0.78**	12.53
	YSC-41 x YST-151	0.84**	12.81	0.64**	12.56
	B-09 x YSH-401	0.55**	12.55	0.61**	12.35
	B-09 x YST-151	0.35**	12.34	0.38**	

***, ** significant at 5 and 1 per cent level, respectively**

Table 5: Estimate of heterosis over superior and economic parent and inbreeding depression in per cent for eight characters in line x tester cross analysis of yellow sarson (*Brassica rapa* var. yellow sarson)

Characters	Cross Combinations	BP (%)	EP (%)	ID (%)	SCA effects	
					F_1	F_2
Number of siliquae per plant	YSC-92 x NRCYS-05-02	3.80**	11.58**	3.20**	0.10**	3.40**
	YSC-45 x NRCYS-05-02	3.09**	2.25**	3.91**	0.77**	0.77**
	YSC-95 x NRCYS-05-02	3.33**	2.03**	6.20**	0.32**	3.10**
	YSC-40 x NRCYS-05-02	3.56**	1.80**	2.98**	2.77**	1.23**
	YSC-84 x NRCYS-05-02	309**	2.25**	3.91**	0.77**	0.77**
Number of seeds per siliqua	YSC-45 x NRCYS-05-02	22.22**	26.92**	6.06**	1.88**	1.27**
	YSC-95 x YSH-401	27.85**	29.49**	10.89**	1.37**	0.73**
	YSC-95 x YST-151	25.32**	26.92**	6.06**	1.30**	1.27**
	YSC-46 x Pitambari	29.49**	29.49**	10.89**	2.37**	0.32**
	YSC-84 x NRCYS-05-02	23.75**	26.92**	6.06**	1.88**	1.27**
Biological yield per plant (g)	YSC-45 x YSH-401	6.52**	13.95**	10.20**	0.38**	0.22**
	YSC-30 x Pitambari	5.56**	10.47**	2.10**	1.97**	0.95**
	YSC-95 x Pitambari	4.26**	13.95**	10.20**	0.03**	0.07**
	YSC-46 x YSH-401	1.04**	10.47**	2.10**	0.12**	1.37**
	YSC-84 x YSH-401	6.52**	13.95**	10.20**	0.38**	0.22**
Harvest index (%)	YSC-45 x YSH-401	5.86**	9.41**	3.19**	1.93**	0.13**
	YSC-30 x NRCYS-05-02	0.95**	9.83**	8.33**	1.59**	0.96**
	YSC-95 x Pitambari	7.86**	9.41**	3.35**	0.79**	0.41**
	YSC-40 x YST-151	4.51**	9.83**	8.33**	1.71**	0.87**
	YSC-84 x YSH-401	8.34**	9.41**	3.19**	1.93**	0.13**
1000-Seed weight (g)	T-42 x NRCYS-05-02	13.36**	15.15**	13.61**	0.04**	0.20**
	T-42 x yst-151	7.97**	17.00**	13.02**	0.03**	0.28**
	Ysk-03 x YST-151	6.26**	15.15**	13.61**	0.16**	0.55**
	YSC-45 x NRCYS-05-02	17.64**	15.15**	13.61**	0.04**	0.20**
	YSC-95 x YST-151	6.26**	15.15**	13.61**	0.16**	0.55**

Oil content (%)	YSC-92 x YST-151	0.82**	0.31**	2.39**	1.00**	0.57**
	YSC-45 x YST-151	4.42**	2.94**	0.17**	0.59**	1.14**
	YSC-30 x YST-151	4.24**	2.76**	0.18**	0.32**	0.10**
	YSC-46 x YST-151	1.75**	0.31**	2.43**	1.00**	0.09**
	YSC-84 x YST-151	4.42**	2.94**	0.21**	0.59**	0.57**
Protein content (%)	YSC-95 x YST-151	9.36**	14.60**	0.37**	1.27**	1.39**
	YSC-40 x YSH-401	11.14**	15.24**	1.30**	1.60**	1.48**
	YSC-46 x YSH-401	9.66**	13.71**	0.66**	0.82**	1.10**
	YSC-84 x NRCYS-05-02	19.14**	14.60**	0.54**	0.94**	1.16**
	YSC-84 x Pitambari	15.24**	15.24**	1.09**	0.54**	0.55**
Seed yield per plant (g)	B-09 x YST-151	20.54**	3.35**	0.10**	0.35**	0.38**
	YSKM-10-02 x YST-151	10.08**	4.02**	9.53**	0.83**	0.87**
	YSC-15 x YST-151	18.91**	3.35**	6.96**	0.35**	0.40**
	YSC-30 x YST-151	7.67**	4.02**	6.86**	0.70**	0.87**
	YSC-84 x YST-151	7.27**	3.35**	7.45**	0.35**	0.63**

***, ** significant at 5 and 1 per cent level, respectively**

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